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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
BEFORE THE BOARD OF PATENT APPEALS AND INTERFERENCES

Docket No: G0533

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In re application of:

Applicant: Arvind Halliyal, et al. Examiner: Long K. Tran

Serial No.: 10/656,470 Art Unit: 2818

Filing Date: September 05, 2003 Confirmation No. 8691

Title: **PREPARATION OF COMPOSITE HIGH-K/STANDARD-K DIELECTRICS FOR SEMICONDUCTOR DEVICES**

APPEAL BRIEF

VIA FACSIMILE
M/S Appeal Briefs - Patents
Commissioner of Patents
P.O. Box 1450
Alexandria, VA 22313

Dear Sir:

This Appeal Brief is submitted in the above-identified application in response to the final Office Action mailed June 10, 2004. Appellants' Notice of Appeal was received in OIPE on June 10, 2004. Accordingly, Appellants' Appeal Brief is timely filed, with no extension of time.

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Dear Sir:

This Appeal Brief is submitted in the above-identified application in response to the final Office Action mailed June 10, 2004. Appellants' Notice of Appeal was received in OIPE on June 10, 2004. This Appeal Brief is submitted in accordance with 37 C.F.R. 41.30-41.54, the rules newly promulgated by the Office and effective as of September 13, 2004, as indicated in 69 Fed. Reg. 155, pp. 50005-50009.

I. REAL PARTY IN INTEREST

The real party in interest in this appeal is Advanced Micro Devices, Inc., One AMD Place, Sunnyvale, California 94088.

II. RELATED APPEALS AND INTERFERENCES

Appellants are aware of no related appeals or interferences.

III. STATUS OF CLAIMS

Claims 1-20 are presently pending in the Application. Claim 8 has been indicated as allowable but for its dependency on a rejected base claim and claims 1-7 and 9-20 stand finally rejected and are the subject of the present Appeal. The Appendix contains a copy of all of claims 1-20.

IV. STATUS OF AMENDMENT

An amendment under 37 C.F.R. 1.116(a) was filed in this application, and the Examiner issued an Advisory Action. Thus, at the present time, there is no amendment pending.

V. SUMMARY OF CLAIMED SUBJECT MATTER

Appellants' invention, in one embodiment as described in claim 1, relates to a semiconductor device having a composite dielectric layer (e.g., Fig. 1, 110), comprising a semiconductor substrate (e.g., p. 11, lines 9-10; e.g., Fig. 1, 102); alternating sub-layers (e.g., p. 11, lines 19-20; e.g., Fig. 1, 110a, 110b, 110c) comprising a first dielectric material and a second dielectric material on the semiconductor substrate (e.g., p. 11, lines 20-22), the sub-layers forming a composite dielectric layer (e.g., Fig. 1, 110) having at least two sub-layers (e.g., Fig. 1, 110a, 110c) of at least one of the first dielectric material and the second dielectric material (e.g., p. 11, lines 22-25), wherein one of the first dielectric material and the second dielectric material is a high-K dielectric material and an other of the first dielectric material and the second dielectric material is a standard-K dielectric material (e.g., p. 12, lines 24-29) comprising aluminum oxide (e.g., p. 14, lines 10-22); and the composite dielectric layer (e.g., Fig. 1, 110) comprises a reaction product (e.g., Fig. 1, 110rp) of the high-K dielectric material and the standard-K dielectric material (e.g., p. 11, lines 22-25).

Appellants' invention, in one embodiment as described in claim 13, relates to a semiconductor device having a composite dielectric layer (e.g., Fig. 1, 110), comprising a

semiconductor substrate (e.g., p. 11, lines 9-10; e.g., Fig. 1, 102); a composite gate dielectric layer (e.g., Fig. 1, 110) on the semiconductor substrate, the composite gate dielectric layer comprising a reaction product (e.g., Fig. 1, 110rp) of a first dielectric material and a second dielectric material (e.g., p. 11, lines 19-25), wherein one of the first dielectric material and the second dielectric material is a high-K dielectric material and an other of the first dielectric material and the second dielectric material is a standard-K dielectric material (e.g., p. 12, lines 24-29) comprising aluminum oxide (e.g., p. 14, lines 10-22); and the reaction product (e.g., Fig. 1, 110rp) comprises a metal aluminate wherein the metal is a high-K derived metal (e.g., p. 15, lines 11-30).

Appellants' invention, in one embodiment as described in claim 16, relates to a semiconductor device having a composite dielectric layer (e.g., Fig. 1, 110), comprising a semiconductor substrate (e.g., p. 11, lines 9-10; e.g., Fig. 1, 102); alternating sub-layers (e.g., p. 11, lines 19-20; e.g., Fig. 1, 110a, 110b, 110c) comprising a first dielectric material and a second dielectric material on the semiconductor substrate (e.g., p. 11, lines 19-25), the sub-layers forming a composite dielectric layer (e.g., Fig. 1, 110) having from 3 to about 10 sub-layers of the first dielectric material and the second dielectric material (e.g., p. 11, lines 26-30; e.g., Fig. 1, 110a, 110b, 110c), each pair of sub-layers separated by a sub-layer of a reaction product (e.g., Fig. 1, 110rp) of the high-K dielectric material and the standard-K dielectric material (e.g., p. 11, line 19 to p. 12, line 8), wherein one of the first dielectric material and the second dielectric material is a high-K dielectric material and an other of the first dielectric material and the second dielectric material is a standard-K dielectric material (e.g., p. 12, lines 24-29) comprising aluminum oxide (e.g., p. 14, lines 10-22).

Appellants note that, in addition to being shown in Fig. 1, the alternating layers of the first and second dielectric materials are also shown in Figs. 4-8 and the reaction product layer, positioned as described above, is also shown in Figs. 7-9.

The present invention addresses the problem of oxidation of silicon by high-K dielectric materials formed in contact with the silicon, by the unexpected expedient of

purposely creating a composite dielectric material including a reaction product of the high-K dielectric material and silicon, silicon dioxide or other standard-K dielectric materials in contact with the high-K dielectric material.

VI. GROUNDS OF REJECTION TO BE REVIEWED ON APPEAL

Claims 1-7 and 9-20 stand rejected under 35 U.S.C. § 102(e), as anticipated by Ma et al, U.S. Patent No. 6,407,435 B1.

VII. ARGUMENT

A. Ma et al., U.S. Patent No. 6,407,435 B1, Fails to Disclose All the Limitations of Appellants' Independent Claims 1, 13 and 16, and Hence All of the Claims Are Patentable Over Ma et al.

Claims 1-7 and 9-20 stand rejected as anticipated by Ma et al., U.S. Patent No. 6,407,435 B1. Appellants respectfully traverse this rejection for at least the following reasons. Appellants respectfully request the Board to reverse the Examiner's rejection of these claims on all grounds and to allow all of the presently pending claims. The rejections are clearly erroneous and contrary to law; accordingly there is no basis for rejecting Appellants' claims and the rejections should be reversed.

1. The Examiner Failed to State a *Prima Facie* Case of Anticipation.

The Examiner in both the first and final Office actions admitted that Ma et al. does not disclose or suggest a reaction product between the high-K dielectric material and the standard-K dielectric material. Because Ma et al. neither disclose nor suggest the existence of any such reaction product, Ma et al. cannot anticipate Appellants' claimed invention as defined in the pending claims, all of which require the presence of such reaction product. For this reason, the Examiner has failed to state a *prima facie* case of anticipation of Applicants' claimed invention by the disclosure of Ma et al.

The Examiner, for the first time in the final Office Action, attempted to overcome this clear evidentiary failure by contending that this feature would have been *Inherent* in Ma et al. The Examiner's mere incantation of the "Inherent" doctrine cannot overcome the clear failure of factual evidence in support of the Examiner's contention. The *only* basis for the contended inherency is the Examiner's contention that some part of the annealing temperature range disclosed by Ma et al. overlaps Appellants' disclosed temperature range, and the Examiner's attempt to bootstrap Appellants' arguments into an admission. The best that can be obtained from the alleged overlap is that the process of Ma et al. *might possibly* attain the conditions required to cause a reaction between the high-K dielectric material and the standard-K dielectric material at their interface. The Examiner's contention fails to provide a sound basis for inherency on both factual and, most importantly, legal grounds. Appellants made no such admission. Simply stated, the Examiner has failed to carry the initial burden of stating a case of inherency, because the contended conditions of Ma et al. *only might possibly, but not necessarily would,* obtain the result taught *only* by Applicants. Furthermore, because absent Appellants' own teaching of the reaction to form a composite layer, no basis whatsoever has been shown to support the contention that a person of ordinary skill in the art would recognize that this reaction would *necessarily* take place.

Since the Examiner failed to carry the initial burden, there is no burden to shift to Appellants to rebut the Examiner's contentions as to inherent disclosure in the reference. As shown by the following, there is no basis in fact or law for the Examiner's contentions.

The Examiner attempted to bolster the contention that Ma et al. inherently would form the claimed composite dielectric material based on an out-of-context statement by Appellants, in which the Examiner contends that Appellants admitted that the claimed composite dielectric material would be formed. In fact, as shown below, Appellants made no such admission, but instead argued and showed that the contended inherent disclosure does not rise to the level of legal inherency.

Accordingly, the rejection of Appellants' claims is clearly erroneous and contrary to the law, and must be withdrawn. Appellants respectfully request the Board to reverse the Examiner's rejection of the presently pending claims.

2. The Disclosure Missing from Ma et al. Is *Not* Inherent in the Reference.

As noted above, the Examiner repeatedly admitted that Ma et al. fail to expressly disclose the formation of a composite dielectric material comprising a reaction product of the high-K dielectric material and the standard-K dielectric material.

Under the doctrine of inherency, if a claimed element is not expressly disclosed in a prior art reference, the reference will still be deemed to anticipate the claim if the missing element "*is necessarily present* in the thing described in the reference, *and* that it would be so *recognized by persons of ordinary skill.*" *Continental Can Co. v. Monsanto Co.*, 20 USPQ2d 1746, 1749 (Fed. Cir. 1991). "Inherent anticipation requires that the missing descriptive material is '*necessarily present*,' not merely probably or possibly present, in the prior art." *Trintec Indus., Inc. v. Top-U.S.A. Corp.*, 63 USPQ2d 1597, 1599 (Fed. Cir. 2002) (quoting *In re Robertson*, 49 USPQ2d 1949, 1950-51 (Fed. Cir. 1999)) (Emphasis added above.). Furthermore, inherent anticipation requires that the necessary presence of the missing descriptive matter would be recognized as being present by persons of ordinary skill in the art. See, MPEP 2163.07(a), which states:

> "To establish inherency, the extrinsic evidence '*must* make clear that the missing descriptive matter is *necessarily* present in the thing described in the reference, and that it would be so recognized by persons of ordinary skill. *Inherency, however, may not be established by probabilities or possibilities. The mere fact that a certain thing may result from a given set of circumstances is not sufficient.*'" In re Robertson, 169 F.3d 743, 745, 49 USPQ2d 1949, 1950-51 (Fed. Cir. 1999) (citations omitted). (Emphasis added.)

In the present case, the Examiner has failed on both counts.

First, the Examiner failed to show that the missing disclosure is necessarily present, rather than it merely may possibly be present under certain conditions, when those conditions are selected by the Examiner. The best the Examiner can do is to assert that under certain conditions, selected from the reference in hindsight, a composite dielectric material might be formed. This is both insufficient and inadequate to support the contended inherency.

Second, the Examiner failed to make any showing that the necessary presence of the missing disclosure would be recognized by those of ordinary skill in the art. The Examiner relied upon Appellants' own disclosure and claims, and attempted to bootstrap Appellants' arguments into an admission that, at certain temperatures, the composite dielectric material would be formed. Appellants submit there was no such admission. The alleged admission was extracted out of context, when Appellants were making the foregoing point about the mere possibility that the reaction might take place. Appellants made no admission such as contended by the Examiner. This alleged admission is both insufficient and inadequate to support the contended inherency.

Therefore, there is no factually or legally correct contention of conclusion that the claimed composite dielectric material is inherent in Ma et al.

3. The Examiner Failed to Show a Sound Basis for Believing That the Products of Applicant and the Prior Art Are Inherently the Same.

Under the law of inherency, as set forth by the Examiner in the final Office Action, it is incumbent upon, that is, it is required of, the Examiner to show *a sound basis* for believing that the products of Applicant and the prior art are inherently the same in order for the Examiner to reject Appellants' claims as anticipated by a reference contended to inherently disclose an element missing from the allegedly anticipating reference. Appellants respectfully submit that the Examiner failed to make any such showing.

The Examiner, having admitted in both the first Office Action and the final Office Action that Ma et al. does not disclose or suggest a composite dielectric material

comprising a reaction product between the high-K dielectric material and the standard-K dielectric material, contends, based on the alleged admission taken out of context from Appellants' arguments in response to the first Office Action, that such was inherent in Ma et al. This contention is clearly erroneous.

The Examiner, at page 3 of the final Office Action, contended:

> Ma et al. do not explicitly specify a reaction product of the high-K dielectric material and the standard-K dielectric material. However, Ma et al. teach a step (550) which is the annealing of the multilayer dielectric stack at temperature range from 400°C to 900°C to condition the high-k layers and the interposing layers (which are low-k layers) as well as the interfaces between the various layers (col. 7, lines 19-28). The device was formed of above combination of references and claimed device are identical in structure. So, it inherently posses the same characteristic as claimed device.

This contention fails to show a sound basis for believing that Appellants' claimed invention is anticipated by Ma et al., even under the doctrine of inherency.

In the Response to Arguments, at page 10 of the final Office Action, the Examiner contended as follows:

> The applicants ague [*sic*, argue] that annealing at temperatures ranging from 400°C to 900°C would be insufficient to form the composite disclosed and claimed by applicants.
>
> The examiner disagrees because the 435's patent disclosed the temperatures ranging from 400°C to 900°C (column 7 lines 25), this range of temperature would be fall within the range temperature of the claimed invention. Further, the applicants has admitted the possibility of causing the reaction to take place between the high K and standard K materials to form a composite dielectric material, as claimed (page 6 last paragraph of the remark), therefore the claimed invention would be anticipated to the 435's patent.

The foregoing statements by the Examiner both mis-stated the Appellants' arguments and failed to show that the claimed invention is anticipated.

With respect to the Examiner's responses to Appellants' arguments, Appellants argued only that a substantial portion of the range of Ma et al. would be insufficient to form the composite dielectric material, and stated, in the context of showing there was no legally

correct contention of inherent disclosure, "the process of Ma et al. *might possibly* cause a reaction to take place between the high-K and standard-K materials to form a composite material, as claimed." In the context of Appellants' argument, this sentence was *immediately* followed by a statement of the law that "probabilities or possibilities are insufficient to prove inherency." The Examiner has improperly taken a selected portion of Appellants' arguments out of its context in an effort to bolster the otherwise unsupportable contention that Appellants admitted the inherency since there is no other "sound basis for believing" the missing disclosure is inherent in the reference. For the Examiner to attempt to use Appellants' arguments in this manner not only fails to support the Examiner's position, but it is also improper since Appellants' arguments have been taken out of context.

Second, as any person of skill in the art would immediately recognize based on Appellants' disclosure (and *not* on that of Ma et al.), the temperature at which a given high-K and a given standard-K dielectric material would react with each other is highly dependent on the exact nature of those materials and other conditions which may affect the reactivity of those materials. Here again, the reaction contended by the Examiner to be inherent might or might not occur, depending on the conditions. This fact again shows that there is no inherent disclosure of Appellants' claimed invention in Ma et al.

Third, it is *only* from Appellants' own disclosure that the Examiner, or a person of skill in the art, might possibly recognize that some of the conditions of Ma et al. might possibly result in the reaction between the high-K dielectric material and the standard-K dielectric material to form the claimed composite dielectric material. It cannot be correct that the Examiner can properly use Appellants' own disclosure to support the contention that the allegedly inherent disclosure necessarily would be recognized by the skilled person.

For these reasons, Appellants submit that the Examiner has failed to show that Ma et al. anticipates the invention described in claims 1-7 and 9-20.

4. The Advisory Acton.

In the Advisory Action mailed July 21, 2004, the Examiner merely reiterated the position that "the claim structure is not patentable over Ma et al. (US Patent No. 6,407,435) for the reasons stated in the Final Office Rejection." Thus, the Examiner wholly failed to address Appellants' arguments made in response to the final Office Action, even though the basis for the rejection was changed from the first Office Action to the final Office Action.

Thus, the Examiner failed to rebut Appellants' arguments and statements of fact relating to the disclosures of the cited reference. For this additional reason, Appellants submit that the Examiner has failed to show that Ma et al. anticipates the invention described in claims 1-7 and 9-20, amd the rejection of Appellants' claims is erroneous and should be reversed. Accordingly, Appellants respectfully request the Board to reverse the Examiner's rejections.

B. Claims 2, 14 and 17 Further Distinguish Over and Are Patentable Over Ma et al. For Additional Reasons.

Claims 2, 14 and 17 further distinguish over Ma et al. and therefore the rejection of these claims over Ma et al. is unsupportable, legally and factually incorrect, and should be reversed, for the following additional reasons.

Each of the independent claims recite that the standard-K dielectric material comprises aluminum oxide. Claims 2, 14 and 17 recite that the standard-K dielectric material further comprises at least one of silicon dioxide, silicon oxynitride, silicon nitride and silicon-rich silicon nitride. Thus, in the embodiments defined by claims 2, 14 and 17, the standard-K dielectric material comprises *both* aluminum oxide *and* at least one of silicon dioxide, silicon oxynitride, silicon nitride and silicon-rich silicon nitride.

Ma et al. fails to disclose or suggest any such combination of materials in the standard-K dielectric materials disclosed therein.

In setting forth the rejection of claims 2, 14 and 17, the Examiner cited Ma et al., col. 4, lines 34-36 as allegedly supporting the rejection. This is clearly erroneous. The disclosure cited by the Examiner reads as follows:

> Interposing layer 130 is composed of aluminum oxide (Al_2O_3), aluminum nitride (AlN), silicon nitride (SiN or Si_3N_4), or silicon dioxide (SiO_2), but preferably aluminum oxide.

There is absolutely no suggestion in this disclosure that the interposing layer could include a mixture of aluminum oxide and any other material.

Accordingly, the Examiner has failed to state a case of anticipation of claims 2, 14 and 17, since the cited reference fails to disclose all the limitations of these claims. Therefore, Appellants respectfully request the Board to reverse the rejection of claims 2, 14 and 17 for this additional reason.

C. Claim 8 Has Been Indicated as Allowable, Further Distinguishes Over and Hence Is Patentable Over Ma et al.

Claim 8 has been indicated as allowable. Claim 8 recites that the composite dielectric layer comprises a substantially uniform layer of the reaction product of the first dielectric material and the second dielectric material.

Ma et al. fails to disclose or suggest any such structure, and the Examiner has admitted such by indicating the allowability of this claim. This claim is allowable; Appellants simply include it here for completeness.

VIII. CONCLUSION

For all these reasons, the rejection of Appellants' claims 1-7 and 9-20 under 35 U.S.C. §102(e) should be reversed because the cited reference fails to teach or disclose, either *in ipsis verbis* or inherently, all of the features of Appellants' claimed invention. Appellants respectfully request reversal of the Examiner's rejections of Appellants' claimed

invention of claims 1-7 and 9-20 under Section 102(e). Appellants respectfully submit that all of the pending claims are in condition for allowance, and respectfully request notice to such effect from the Examiner and/or the Board.

In the event issues remain in the prosecution of this application, Appellants request that the Examiner telephone the undersigned attorney to expedite further consideration and/or allowance of the claims of this application. **The Commissioner is authorized to charge the fee of $330.00 for the filing of an Appeal Brief to Deposit Account #18-0988, Docket No. G0533, AMDSPG0533USA.** Should a Petition for Extension of Time be necessary for the present Appeal Brief to be timely filed (or if such a petition has been made and an additional extension is necessary) petition therefor is hereby made and, if any additional fees are required for the filing of this paper, the Commissioner is authorized to charge those fees to Deposit Account #18-0988, Docket No. G0533, AMDSPG0533USA.

Respectfully submitted,

RENNER, OTTO, BOISSELLE & SKLAR

Date: September 30, 2004

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APPENDIX:

CLAIMS

1. A semiconductor device having a composite dielectric layer, comprising:

a semiconductor substrate;

alternating sub-layers comprising a first dielectric material and a second dielectric material on the semiconductor substrate, the sub-layers forming a composite dielectric layer having at least two sub-layers of at least one of the first dielectric material and the second dielectric material,

wherein one of the first dielectric material and the second dielectric material is a high-K dielectric material and an other of the first dielectric material and the second dielectric material is a standard-K dielectric material comprising aluminum oxide; and

the composite dielectric layer comprises a reaction product of the high-K dielectric material and the standard-K dielectric material.

2. The semiconductor device of claim 1, wherein the standard-K dielectric material further comprises at least one of silicon dioxide, silicon oxynitride, silicon nitride, and silicon-rich silicon nitride.

3. The semiconductor device of claim 1, wherein the high-K dielectric material comprises at least one of hafnium oxide (HfO_2), zirconium oxide (ZrO_2), tantalum oxide (Ta_2O_5), barium titanate ($BaTiO_3$), titanium dioxide (TiO_2), cerium oxide (CeO_2), lanthanum oxide (La_2O_3), lanthanum aluminum oxide ($LaAlO_3$), lead titanate ($PbTiO_3$), strontium titanate ($SrTiO_3$), lead zirconate ($PbZrO_3$), tungsten oxide (WO_3), yttrium oxide (Y_2O_3), bismuth silicon oxide ($Bi_4Si_2O_{12}$), barium

strontium titanate (BST) ($Ba_{1-x}Sr_xTiO_3$), PMN ($PbMg_xNb_{1-x}O_3$), PZT ($PbZr_xTi_{1-x}O_3$), PZN ($PbZn_xNb_{1-x}O_3$), and PST ($PbSc_xTa_{1-x}O_3$).

4. The semiconductor device of claim 1, wherein the reaction product comprises a high-K derived metal atom, an aluminum atom and an oxygen atom.

5. The semiconductor device of claim 1, wherein the first dielectric material is the high-K dielectric material.

6. The semiconductor device of claim 1, wherein the second dielectric material is the high-K dielectric material.

7. The semiconductor device of claim 1, wherein the composite dielectric layer comprises at least a portion of the sub-layers of the first dielectric material and the second dielectric material, separated by a sub-layer of a reaction product of the first dielectric material and the second dielectric material.

8. The semiconductor device of claim 1, wherein the composite dielectric layer comprises a substantially uniform layer of the reaction product of the first dielectric material and the second dielectric material.

9. The semiconductor device of claim 1, wherein the composite dielectric layer comprises from 3 to about 10 sub-layers of the first dielectric material and the second dielectric material.

10. The semiconductor device of claim 9, wherein each pair of sub-layers of the first dielectric material and the second dielectric material are separated by a reaction product sub-layer.

11. The semiconductor device of claim 1, wherein the composite dielectric layer is a gate dielectric layer in the semiconductor device.

12. The semiconductor device of claim 1, wherein the composite dielectric layer is a gate dielectric layer formed on the semiconductor substrate.

13. A semiconductor device having a composite dielectric layer, comprising:

a semiconductor substrate;

a composite gate dielectric layer on the semiconductor substrate, the composite gate dielectric layer comprising a reaction product of a first dielectric material and a second dielectric material,

wherein one of the first dielectric material and the second dielectric material is a high-K dielectric material and an other of the first dielectric material and the second dielectric material is a standard-K dielectric material comprising aluminum oxide; and

the reaction product comprises a metal aluminate wherein the metal is a high-K derived metal.

14. The semiconductor device of claim 13, wherein the standard-K dielectric material further comprises at least one of silicon dioxide, silicon oxynitride, silicon nitride, and silicon-rich silicon nitride.

15. The semiconductor device of claim 13, wherein the high-K dielectric material comprises at least one of hafnium oxide (HfO_2), zirconium oxide (ZrO_2), tantalum oxide (Ta_2O_5), barium titanate ($BaTiO_3$), titanium dioxide (TiO_2), cerium oxide (CeO_2), lanthanum oxide (La_2O_3), lanthanum aluminum oxide ($LaAlO_3$), lead titanate ($PbTiO_3$), strontium titanate ($SrTiO_3$), lead zirconate ($PbZrO_3$), tungsten oxide (WO_3), yttrium oxide (Y_2O_3), bismuth silicon oxide ($Bi_4Si_2O_{12}$), barium

strontium titanate (BST) ($Ba_{1-x}Sr_xTiO_3$), PMN ($PbMg_xNb_{1-x}O_3$), PZT ($PbZr_xTi_{1-x}O_3$), PZN ($PbZn_xNb_{1-x}O_3$), and PST ($PbSc_xTa_{1-x}O_3$).

16. A semiconductor device having a composite dielectric layer, comprising:

a semiconductor substrate;

alternating sub-layers comprising a first dielectric material and a second dielectric material on the semiconductor substrate, the sub-layers forming a composite dielectric layer having from 3 to about 10 sub-layers of the first dielectric material and the second dielectric material, each pair of sub-layers separated by a sub-layer of a reaction product of the high-K dielectric material and the standard-K dielectric material,

wherein one of the first dielectric material and the second dielectric material is a high-K dielectric material and an other of the first dielectric material and the second dielectric material is a standard-K dielectric material comprising aluminum oxide.

17. The semiconductor device of claim 16, wherein the standard-K dielectric material further comprises at least one of silicon dioxide, silicon oxynitride, silicon nitride, and silicon-rich silicon nitride.

18. The semiconductor device of claim 16, wherein the high-K dielectric material comprises at least one of hafnium oxide (HfO_2), zirconium oxide (ZrO_2), tantalum oxide (Ta_2O_5), barium titanate ($BaTiO_3$), titanium dioxide (TiO_2), cerium oxide (CeO_2), lanthanum oxide (La_2O_3), lanthanum aluminum oxide ($LaAlO_3$), lead titanate ($PbTiO_3$), strontium titanate ($SrTiO_3$), lead zirconate ($PbZrO_3$), tungsten oxide (WO_3), yttrium oxide (Y_2O_3), bismuth silicon oxide ($Bi_4Si_2O_{12}$), barium strontium titanate (BST) ($Ba_{1-x}Sr_xTiO_3$), PMN ($PbMg_xNb_{1-x}O_3$), PZT ($PbZr_xTi_{1-x}O_3$), PZN ($PbZn_xNb_{1-x}O_3$), and PST ($PbSc_xTa_{1-x}O_3$).

19. The semiconductor device of claim 16, wherein the composite dielectric layer is a gate dielectric layer in the semiconductor device.

20. The semiconductor device of claim 16, wherein the composite dielectric layer is a gate dielectric layer formed on the semiconductor substrate.